

Mechanical properties of black sugar palm fiber-reinforced concrete

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Since 1960 s, research work on fiber-reinforced concrete have been carried out extensively leading to a wide range of practical applications. As a result, there exists today a wide range of fiber types available for use as fibers in concrete. These include steel, asbestos, glass, ceramic, polymer, and natural fibers such as hemp, sisal, cotton, coconut, and palm. Many research works have been carried out using steel, polymer, and glass.¹⁻³ However, investigations on the use of natural fiber are rather limited and surely reported in the literature^{4,5} compared to non-natural fibers such as steel and plastic.

Principally, the sources of natural fiber are found in several plants, but not all are suitable for use as fibers in concrete. The advantage of using natural fibers is that they are readily available, environment-friendly, and cheap since the production cost is lower than nonnatural fibers. The major problems associated with the use of natural fibers are due to poor durability, low modulus of elasticity, poor bonding, and poor fire resistance. Natural fibers have been used in soil cement construction⁶ but their application is mainly in non-structural components such as roofing tiles, concrete masonry blocks, slab for roofing, and construction of water tanks.

Recent studies using natural fibers such as sugarcane bagasse⁴ and cellulose fiber⁷ have shown that incorporation of these fibers enhanced the compressive strength, tensile strength, flexure strength, toughness, and impact resistance.

This study is concerned with the engineering properties of concrete containing palm fiber as reinforcement. The effect of fibers in concrete depends on two important parameters, namely fiber volume fraction and aspect ratio. Fiber volume fraction is the amount of fibers added to a concrete mix expressed as a percentage of the total volume of the composite. Aspect ratio is calculated by dividing the fiber length by its diameter. The performance of fiber-reinforced concrete also depends on the matrix mix ingredients.¹ The matrix strength of fiber-reinforced concrete, which has a significant influence on the toughness characteristic, is dependent on the geometry, type, volume fraction of fiber, and bond strength of fiber in the matrix.

The addition of fibers to a concrete mix causes a reduction in the workability, normally indicated by low slump value. Fibers have relatively large surface area and as a result the water requirement for a given workability is much higher. This problem can be overcome by the use of water-reducing admixture or superplasticizer¹ in the concrete mix. The physical properties of the fiber influencing workability are the aspect ratio and the volume percent of fiber. In general, an aspect ratio of less than 100 and fiber content not higher than 2% represent the maximum limit to obtain a mix with good workability.⁸ Higher fiber content leads to reduced workability and longer mixing time. As the fibers are added to the fresh concrete mix manually in the mixer, the dispersion is not uniform and may result in 'balling.' Fiber dispersion in the wet mix is also an important factor in the case of properties of the concrete such as compressive strength, flexural strength, and toughness.

Experimental work

Materials

Locally produced ordinary Portland cement (OPC)

equivalent to ASTM Type 1 was used. The coarse aggregate was crushed granite ranging between 4.75 and 19mm in size. The fine aggregate was siliceous sand and consists of the combination of particle size according to ASTM sieve sizes, namely coarse (8–16 mesh), medium (20–40 mesh), and fine (40–60 mesh). A sulfonated naphthalene formaldehyde-based superplasticizer with 40% solid content was added to achieve a slump value within the range 70–100mm for each mix at a constant water/cement ratio of 0.4. Mixing and curing water was taken directly from tap supply. The fibers used were obtained from the trunk of the black sugar palm or commonly known in Indonesia as the Ijuk tree. The Latin name of this particular species of palm is *Arenga Pinnata* and can be found widely in the swamp forests of South East Asia and India. The fibers were untreated, before concreting; the fibers were cleaned and cut to the required size i.e., 15, 25, and 35 mm. The physical and mechanical properties of the palm fibers are given in Table 1. The results were obtained from test on 10 fiber specimens. A total of 13 mixes, which include the plain concrete mix which acts as the control and 12 fiber-reinforced concrete mixes with fiber lengths 15, 25 and 35mm in four volume fractions 0.2%, 0.4%, 0.6%, and 0.8% were produced. Table 2 presents the mix proportions used in the investigation.

Specimen preparation and test procedures

Two types of concrete specimens were used in this investigation. They were 100_100_100mm³ cubes and 100_100_500mm³ prisms for the determination of compressive strength and flexural toughness, respectively. Mixing of the ingredients was carried out using a pan mixer and the sequence of mixing can be summarized as follows: aggregates and cement were mixed dry for approximately 1½ minutes,

and then three quarters of the mixing water was added, followed by the superplasticizer, and finally the remaining water. In the case of the fiber concrete, after the last water, the fibers were added to the wet mix and gradually in small amounts to avoid clustering. The mixing was continuing approximately 1 min after the last fiber added. The specimens were demolded after 24 h and subjected to full water curing in a tank until the age of testing.

The workability of fresh concrete was measured using the slump test. The compressive strength and flexural toughness of the concrete were tested in accordance with BS 1881: Part 116: 1983 and ASTM C1018–94 b, respectively. The strength development was monitored at 3, 7, 28, 56, and 90 days.

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